COS 598: Adv. Topics in CS – Image Processing and Analysis
Spring 2022: Section 2
Instructor: Prof. Terry Yoo

Homework Assignment 3: Applying filters and Basic Segmentation methods

This assignment asks you to explore some of the filters and techniques that have been mentioned in class. There are three parts to this assignment.

1. Linear filtering.

In this part, you will compare continuous functions with computing functions using linear filters of sampled, discrete image data.

You are asked to generate a 2D first derivative of an isotropic (round) Gaussian with respect to x directly from the analytic expression of the equation. You are asked to generate an isotropic Gaussian, and then filter it with a 3x3 derivative filter. The third step is to compare the two output images.

A. Continuous version: Write a program (using Python and SimpleITK… you may adapt a Jupyter notebook) to generate a 256 x 256 image of a background b on which is superimposed a *1st derivative with respect to x of an isotropic* Gaussian spot of intensity f centered at location $\bar{\mu} = (x_0, y_0)$. The function will be amplified by a factor a.

   You can simply adjust your program for assignment 2 or since the assignment is based on an isotropic Gaussian, you can use the following simplified equation(s).

$$f = a\left(\frac{1}{2\pi\sigma^2} e^{-\frac{1}{2}\frac{(x-x_0)^2+(y-y_0)^2}{\sigma^2}}\right) + b \tag{1}$$

   Equation (1) is the equation for an isotropic Gaussian.

$$\frac{\partial f}{\partial x} = a\frac{\partial}{\partial x}\left(\frac{1}{2\pi\sigma^2} e^{-\frac{1}{2}\frac{(x-x_0)^2+(y-y_0)^2}{\sigma^2}}\right) = a\left(\frac{1}{2\pi\sigma^2}\frac{(x-x_0)}{\sigma^2} e^{-\frac{1}{2}\frac{(x-x_0)^2+(y-y_0)^2}{\sigma^2}}\right) \tag{2}$$

   Equation (2) is the equation for the 1st derivative with respect to x of an isotropic Gaussian.

   You may choose any convenient values for a and b. You may also choose to offset the derivative of the Gaussian by a factor b. You should use the following specific values for your image:

$$x_0 = y_0 = 128, \sigma = 20.$$

If you are modifying your program from assignment 2,

$$x_0 = y_0 = 128, \sigma_x = \sigma_y = 20, \theta = 0.$$

B. Discrete version:

B1. Generate a 256 x 256 image of a background b on which is superimposed *an isotropic* Gaussian spot of intensity f centered at location $\bar{\mu} = (x_0, y_0)$. The function will be amplified by a factor a.

You can simply adjust your program for assignment 2 or since the assignment is based on an isotropic Gaussian, you can use equation (1).

You may choose any convenient values for a and b. You should use the following specific values for your image:

$$x_0 = y_0 = 128, \sigma = 20.$$

If you are modifying your program from assignment 2,

$$x_0 = y_0 = 128, \sigma_x = \sigma_y = 20, \theta = 0.$$

B2. Convolve a 3x3 derivative filter with the output from part B1. Use the following filter kernel:

$$\frac{1}{6}\begin{array}{|c|c|c|}\hline -1 & 0 & 1 \\ \hline -2 & 0 & 2 \\ \hline -1 & 0 & 1 \\ \hline \end{array}$$

C. Subtract the resulting images from part 1A and part 1B to compare them. Write a brief description of your findings.

2. Removal of unwanted signal.

Consider the aerial images from Dr. Noah Charlton of the conservation land outside Nashville, Tennessee. The goal is to estimate the amount of biomass represented by fallen trees. This problem is confounded by the shadows cast by the standing trees. The shadows are signal, valid data accurately recorded in the remote sensing images. However, for this task, these data are unwanted and confound the attempt to detect fallen trees.

The images below are also available as .jpg images. You may use any set of tools available at your disposal, including Fiji, SimpleITK, Photoshop, custom Python programs, or other systems with which you have experience. Using any combination of the techniques that we have discussed in class, attempt to remove the shadows cast by the standing trees to help expose and detect the fallen logs in the images. You may use thresholding, binary image morphology, linear filtering, scale space detection, convolution/correlation with custom oriented kernels, or other techniques to try and remove the shadows.

a. b. c.

Figure 1. The images show three aerial images of the same patch of the conservation land outside Nashville, TN. 1a. Patch 39-53 from 2014. 1b. Patch 39-53 from 2016. 1c. Patch 39-53 from 2017. The images were taken at different times of day. The shadows are aligned in different directions.

Alternately, you might consider enhancing and isolating the shadows to create a map or mask of the shadows, then use that mask to remove them from the image(s).

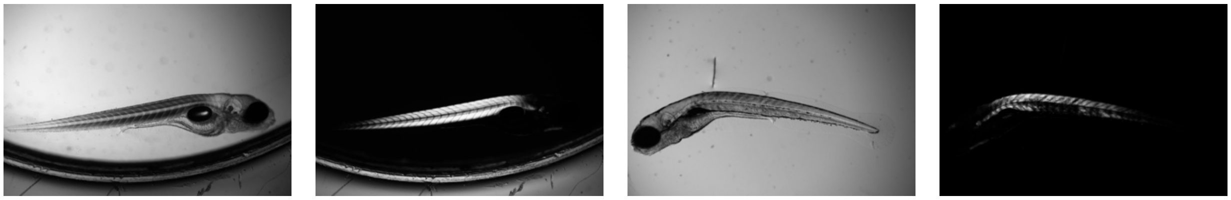
The example includes three images of the same patch. You may use multiple views of the same patch to try to suppress the shadows.

There is no correct answer to this problem. The purpose of this exercise is to familiarize you with multiple techniques, to try different methods, and to explore the domain of linear and nonlinear methods on a real problem.

3. Basic segmentation methods.

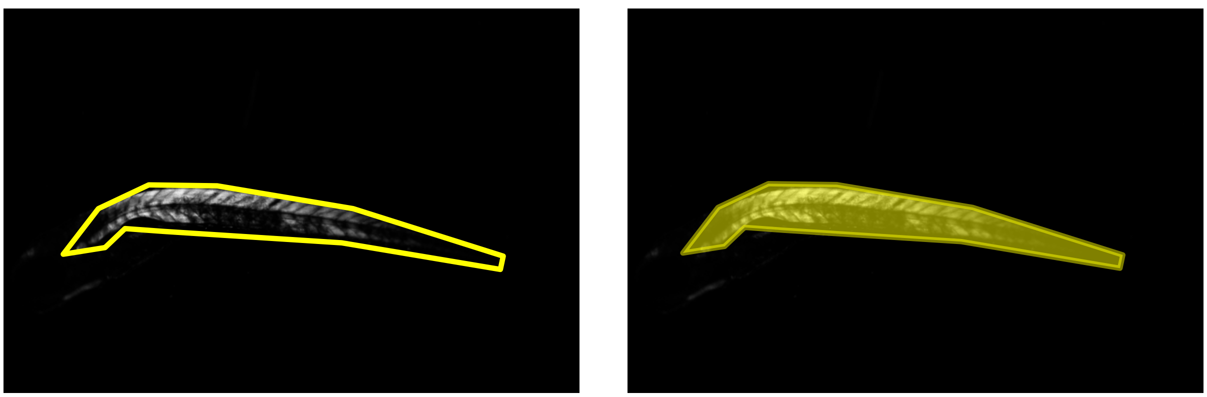
Consider the light-sheet microscopy images from Dr. Clarissa Henry's lab of zebrafish, both the bright field images and the birefringence images. The goal is to use image processing methods to create a segment, outline, or mask of the musculature. Especially in abnormal cases, the intention is to show where the muscles should be in a normal fish in order to calculate the deficit in muscle mass.

The images below are also available as PNG images. You may use any set of tools available at your disposal, including Fiji, SimpleITK, Photoshop, custom Python programs, or other systems with which you have experience. Using any combination of the techniques that we have discussed in class, attempt to create a segment or outline of the muscle structure.



a. b. c. d.

Figure 2. The images show 2a. bright field image of normal zebra fish. 2b. birefringence image of the normal zebrafish in Fig. 2a highlighting the muscle tissue. 2c. bright field image of zebra fish with muscular dystrophy. 2d. birefringence image of the zebrafish in Fig. 2c highlighting the muscle tissue.



a. b.

Figure 3. An example of the desired segmentation mask. You do not have to create the outline shown in Figure 3a. It will be sufficient to create a binary mask image with the shape and dimension shown in Figure 3b.

One possible approach is to use a threshold to create a binary image of the birefringence image, then using binary mathematical morphology attempt to *close* (dilate, then erode) the gaps using a fairly large structuring element.

The example includes two images of the two fish, one normal, and one with muscular dystrophy. You may use both images or you may attempt to use individual images.

There is no correct answer to this problem. The purpose of this exercise is to familiarize you with multiple techniques, to try different methods, and to explore the question of segmentation.

Submit the text part of your answers on Brightspace as either a PDF or MSWord document.
Submit any source code and images via e-mail to cos.computer.vision@maine.edu.
Due 11-April-2022